# Tidal Channel Dynamics and Muddy Substrates: a Comparison Between a Wave Dominated and a Tidal Dominated System

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## LONG-TERM GOALS

- To quantify the relationships between resuspension of fine material in the shelf by wind waves, tidal channels hydrodynamics, and sediment supply to coastal marshes.

- To develop predictive, high-resolution models for the hydrodynamics and sediment dynamics of tidal channels in muddy coastal environments

- To develop methods to predict the long-term evolution of tidal channels in muddy coastlines as a function of sediment availability, hydrodynamics, and climate change.

## OBJECTIVES

- To determine the feedbacks between waves, tidal fluxes and tidal channels in muddy coastlines
- To link the geotechnical properties of sediment substrates to the spatial and hydrodynamic characteristics of tidal channels
- To develop new morphological indicators of tidal flat morphodynamics that can be easily derived from remote sensing images. To link these indicators to mechanical properties of tidal flat substrates
- To compare the results of the MURI project "Mechanisms of Fluid Mud Interactions under Waves" to wave measurements at the shoreline.
- To integrate high resolution hydrodynamic measurements within ongoing research activities at the Willapa Bay "Tidal Flats" DRI location

## APPROACH

We propose to determine how tidal fluxes and waves affect the distribution of channels in muddy environments and, vice versa, how tidal channels modify tidal circulation and wave distribution. Moreover our project will determine the relationships between the mechanical properties of the mud substrate and intertidal morphology. To accomplish this task we will compare two mud dominated environments. Little Constance Bayou, in Louisiana, and Willapa Bay, in Washington State. In Little

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Constance Bayou waves propagating from offshore have a strong impact on coastal morphology, whereas in Willapa Bay the large tidal excursion is the driving mechanism for sediment transport.

**WORK COMPLETED**

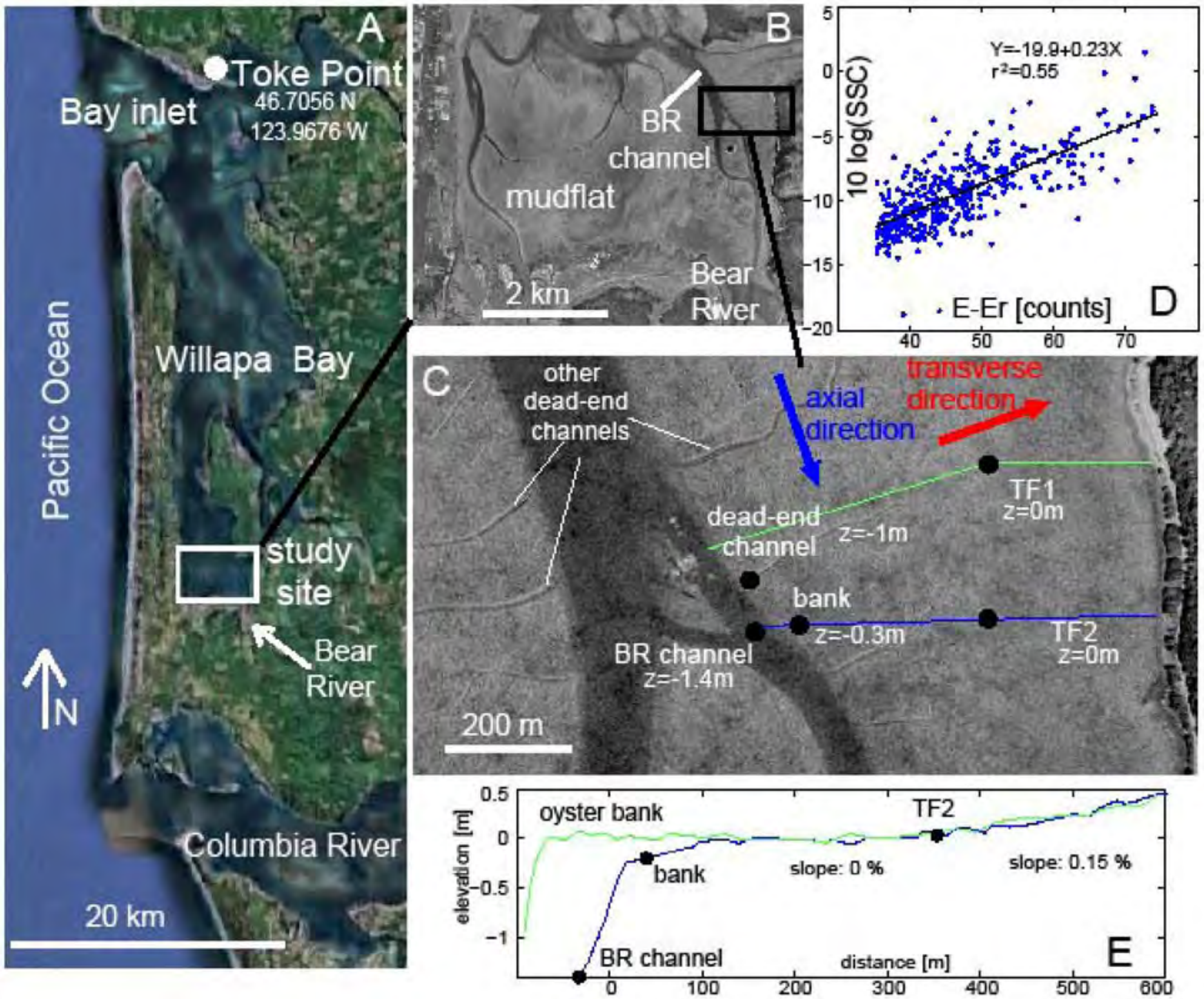


***Figure 1 Figure 1. A) Location of Willapa Bay, Washington State, USA. B) Detail of the inner mudflat of Willapa Bay. C) Instrument deployment with position of the five ADCPs. D) Calibration of the ADCP backscatter with the suspended sediment concentration. E) Topographic transect from a local survey. The location of the transect is shown in Fig 1C.***

We have spent fiscal year 2010-2011 analyzing the large volume of data collected in Willapa Bay in 2010. Five Acoustic Doppler Current Profiler (ADCP) were deployed for 46 days (from 2/21 to 4/9 2010) for a total of 90 tidal cycles in Willapa Bay, Washington State, USA. Two ADCPs were placed on the tidal flat (TF1, TF2), one at the mouth of a dead-end channel, one inside the BR channel, and one on the tidal flat next to the BR channel (channel bank) (Fig 1C). The ADCPs were deployed directly on the bed surface in the upward looking configuration. Near the bank site the BR channel

bifurcates in two branches, which reconnect after 1 km. The east branch is about 60 m wide and 2 m deep with respect to the tidal flat, the west branch is about 80 m wide and 3 m deep. The ADCP in the BR channel was deployed in the east branch (see Fig 1C). Finally, an Optical Backscatter Sensor (OBS) was deployed with the ADCP in the dead-end channel at 20 cm from the channel bottom.
A topographic survey reveals that the mudflat is approximately flat along the N-S direction, at the spatial scale of the tidal flat width (500 m). A bottom slope is present in the W-E direction, but only within the last 250 m close to the landward boundary, varying gradually from 0.1% to 1% (Fig 1E). The mudflat is placed 0.7 m below mean sea level (MSL), and its elevation is set herein equal to zero in a local coordinate system. The two instrument sites on the tidal flat are placed at the same elevation; the bottom of the dead-end channel is 1m below the tidal flat, the bank site (low tidal flat) is 0.3m below the tidal flat, and the site in the BR channel is 1.4 m below the tidal flat elevation.
Velocity profiles were measured with the ADCPs at 2 Hz every 30 minutes, averaging over 60 s, with a vertical cell size of 10 cm and a blanking distance of 10 cm. Water depth was calculated using the pressure measured by the ADCPs' piezometers. The pressure was corrected with the atmospheric pressure measured at the NOAA station at Toke Point (station 9440910). Water level was obtained by adding the bed elevation (measured during the survey) to the water depth.

At every location, a wave burst of 512 points was hourly sampled at 2 Hz. The surface wave spectrum was reconstructed from each wave burst using the standard linear wave theory.

Suspended sediment concentration (SSC) was estimated using the backscatter signal of the ADCP and the turbidity value measured by the OBS when present.

The OBS turbidity signal was calibrated against SSC measured in a laboratory tank, using sediments collected on the tidal flat. The OBS was present only at the dead-end channel site.

## RESULTS

Suspended sediment concentration (SSC) shows a recursive pattern between different tidal cycles (Fig.2). We measured a lateral circulation between a large flow-through channel and the adjacent tidal flat in Willapa Bay (Fig. 1). The corresponding fluxes are characterized by higher velocities at the beginning of the tidal flat inundation and at the end of the tidal flat drainage (see also Nowacki and Ogston, 2011). A simplified barotropic model suggests that this lateral circulation is generated by the differential longitudinal velocities between the main channel and the tidal flat. This model allows estimating the lateral circulation by continuity arguments only, without knowing the form of the tidal wave propagation.

The lateral circulation is characterized by a flux of sediment directed from the BR channel to the tidal flat during flood. This flux likely originates from the elevated SSC in the BR channel and is transported across the bank without significant change. The advection of sediment from the BR channel contributes to the formation of the turbid tidal edge measured on the tidal flat (Hsu et al. 2001).

Even though observations suggested the importance of sediment advection from channels (e.g. Ridderinkhof et al., 2000, Warner et al. 2004), this contribution has never been emphasized and described in detail, and has not been related to the formation of the turbid tidal edge.

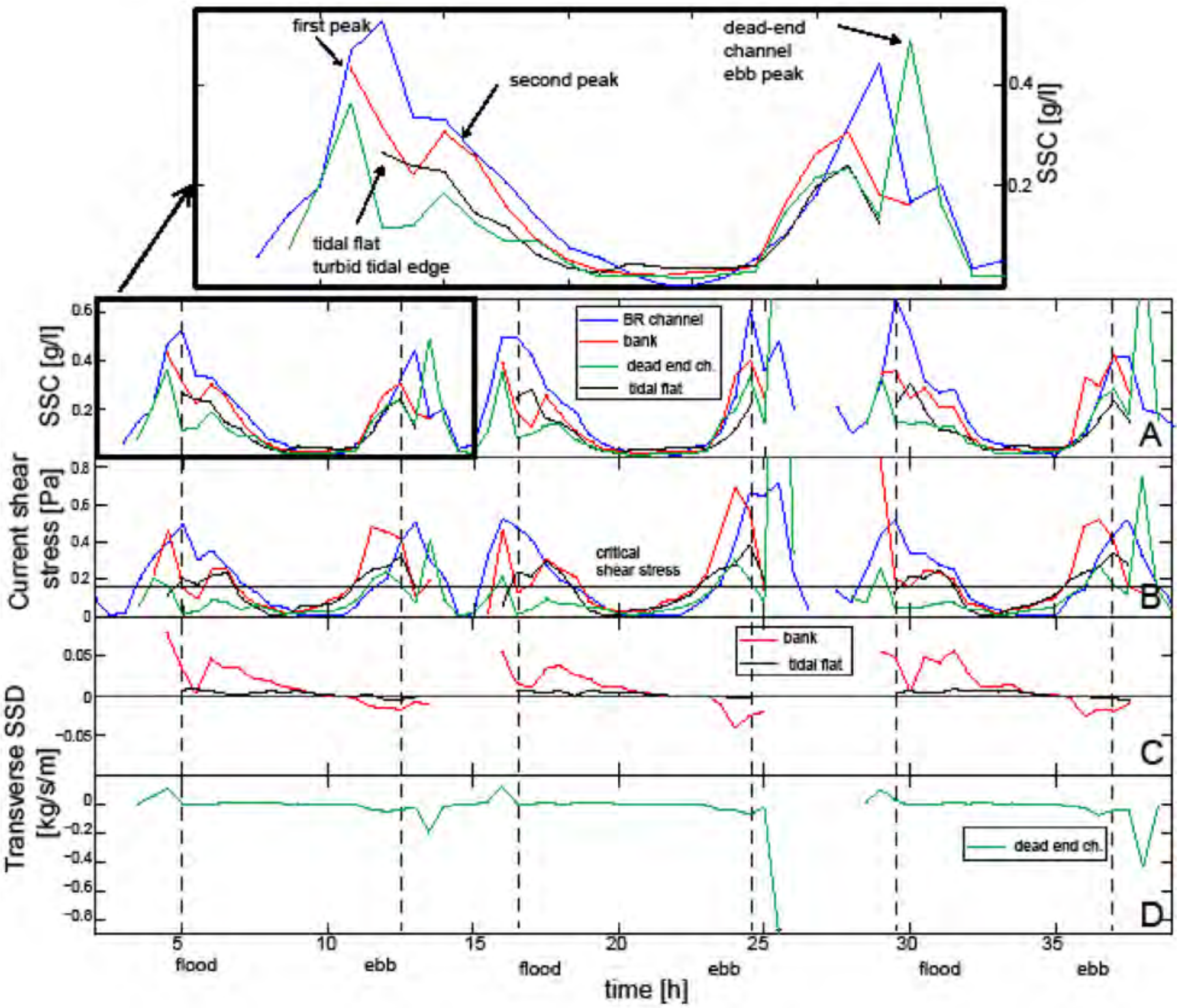


***Figure 2. Suspended sediment concentration (SSC) measured from 3/3 to 3/6 2010 at different locations. A) SSC in the BR channel, bank, dead-end channel and tidal flat. B) Current induced shear stress in the BR channel, bank, dead-end channel and tidal flat. The horizontal black line defines the critical shear stress, set equal to 0.15 Pa. C) Transverse suspended sediment discharge at the bank and on the tidal flat. D) Transverse suspended sediment discharge in the dead-end channel.***

We propose a simple mechanism, which stems from two conditions: 1) higher SSC in the main channel than on the tidal flat, 2) water diverging from the channel during flood and converging during ebb. According to the channel spillover mechanism, sediments are brought from the main channel to the tidal flat during flood, but not during ebb, generating a net accumulation on the tidal flat.

This mechanism can either act independently or interact with other sedimentary processes present on the tidal flat. Tidal asymmetries in duration, velocity, or stratification are not altering the mechanism, provided that conditions 1) and 2) are present. However, the presence of wind waves increases SSC on the tidal flat more than in the BR channel, reversing the channel spillover mechanism. Is therefore

clear that a complete understanding of the tidal flat sediment dynamics requires the coupling between these processes.

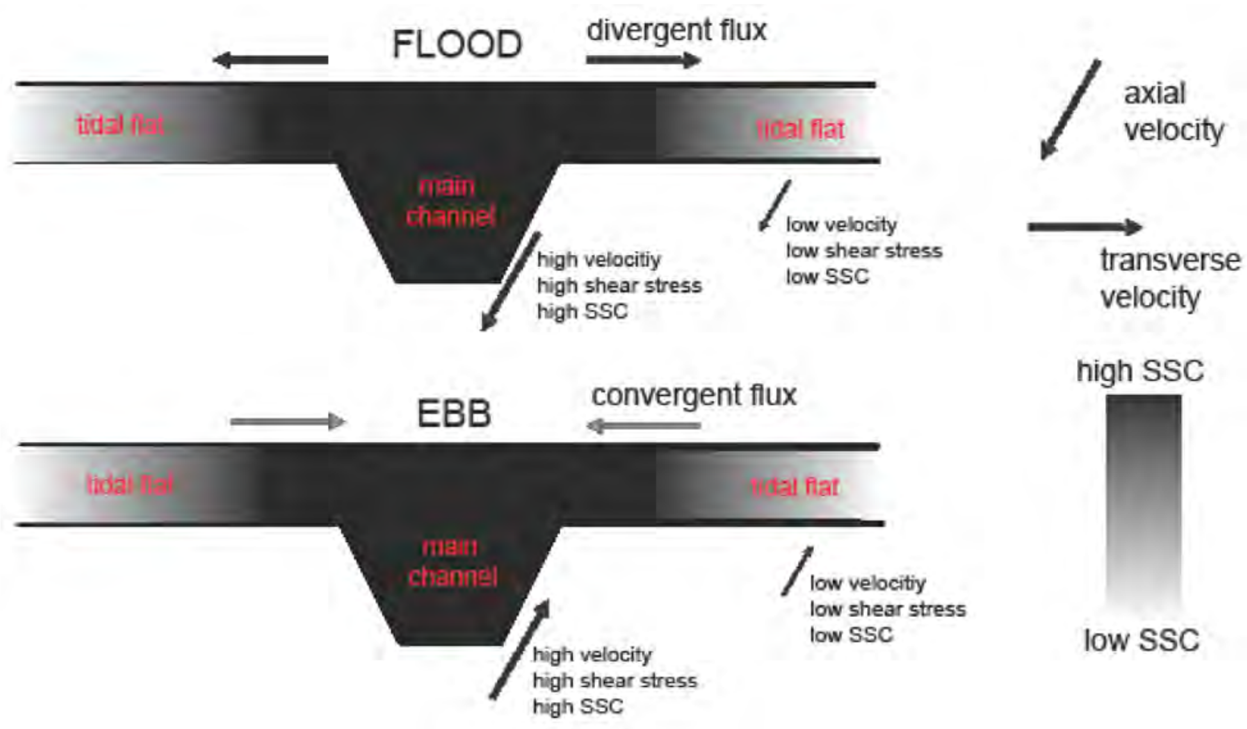


***Figure 3. Cartoon describing the channel spillover mechanism. Axial velocities and suspended sediment concentration are greater in the channel than on the tidal flat during both ebb and flood. Transverse flow is directed from the channel to the tidal flat during flood and from the tidal flat to the channel during ebb. Transverse sediment discharge is higher during flood than during ebb.***

## IMPACT/APPLICATIONS

The collected data will help assessing the navigability and trafficability of mudflats and tidal channels in denied areas. Moreover, the characterization of wave climate along a muddy coast will provide useful information for navigation in very shallow water and landing. Finally, the feedbacks between tides, waves and sediment transport will provide information on the evolution of mudflat environments and their morphological characteristics.

## RELATED PROJECTS

The proposed research is designed to synergistically complement the ONR- MURI project “Mechanisms of Fluid Mud Interactions under Waves” and the Willapa Bay “Tidal Flats” ONR-DRI project

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